

# Development of the Vertically Complete Duodecaplets

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Presentation to the Natural Environments Day of Launch  
Working Group (NEDOLWG)

# **This presentation summarizes the methodology to develop the vertically-complete duodecaplets.**

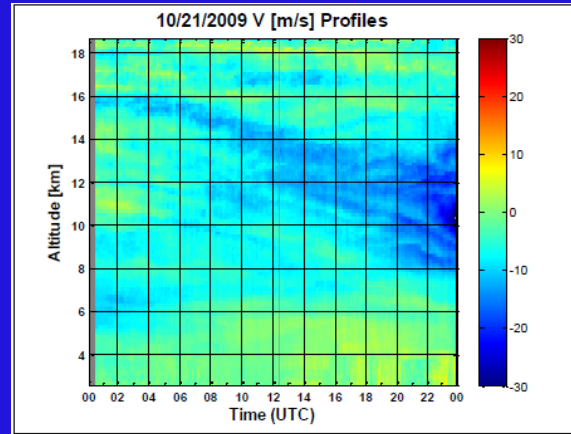
1. Background of the seasonal atmosphere/wind databases
2. Generation of ground wind profile output
3. Source of ground wind profiles
4. Verification of wind profile output
5. Summary and forward work

# Seasonal atmosphere/wind databases developed from DRWP profiles and GRAM

50-MHz DRWP (TDRWP)



915-MHz DRWP

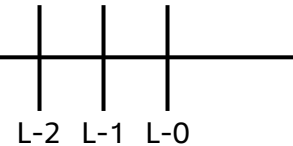


- Spliced DRWP Archive
- 2000-2009 period of record (POR)
  - 5-min reports
  - Altitude: 0.25-18.45 km

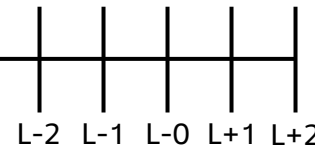
## Added Earth-GRAM Output

- Variables: T, p,  $\rho$ , U, V

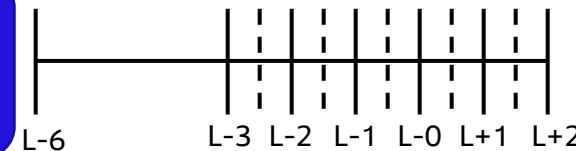
### Triplets



### Quintuplets



### Duo-decaplets



# Purpose of seasonal atmosphere/wind databases

## Triplets

- Mimics DOL timeline: design at L-2, check at L-1, launch at L-0
- 4000 triplets per season; maximized time delta between sets to obtain 4000
- Used in DAC-3

## Vertically Complete

- Ground winds added to the L-0 profiles from the triplets
- 2000 per season. Subset of the triplets
- Used in Orion pad abort assessments

## Quintuplets

- Added 2 profiles in order to cover 2 hr launch window
- 2000 quintuplets per season. Subset of the triplets (different from vertically complete)
- L-0, L+1, and L+2 profiles are from the triplet database; added L-2 and L-1 profiles
- Used in VAC-1 and DOLILU

## Duodecaplets

- Includes L-6 and L-3 profiles, with 30-min interval between L-3 and L+2
- More profiles needed for robust DOL assessments (e.g., design at L-2.5, check at L-1.5, etc.)
- No time delta criteria; obtained as many duodecaplets as possible (Winter: 3715, Transition: 3799, Summer: 5550)
- Used in FRAC and DOLILU

- Note: All databases are captured in SLS Natural Environments documentation
- Orion requested MSFC Natural Environments to add tower data to the duodecaplets to provide higher fidelity wind input to Artemis II Mission Analysis Cycle pad abort assessments stemming from SLS trajectories

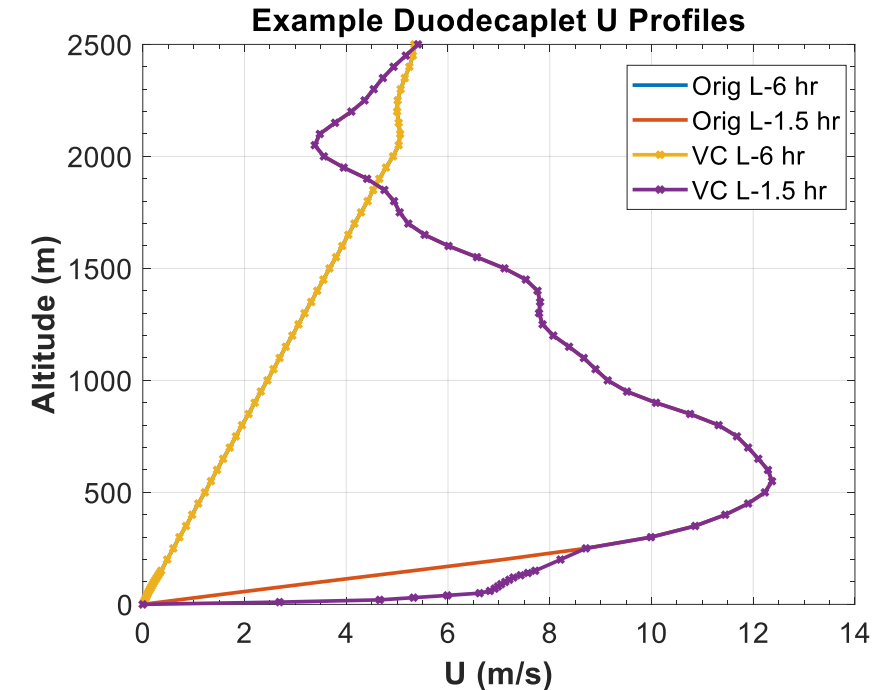
# Adding tower measurements to the bottom of the duodecaplets increases data fidelity below 250 m altitude.

## Original Duodecaplets

- 50-m altitude increments below 20 km.
- Wind component “ramp” from lowest measurement to 0 m/s at 0 m.
  - L-6: up to 2.7 km
  - Other profiles: 250 m

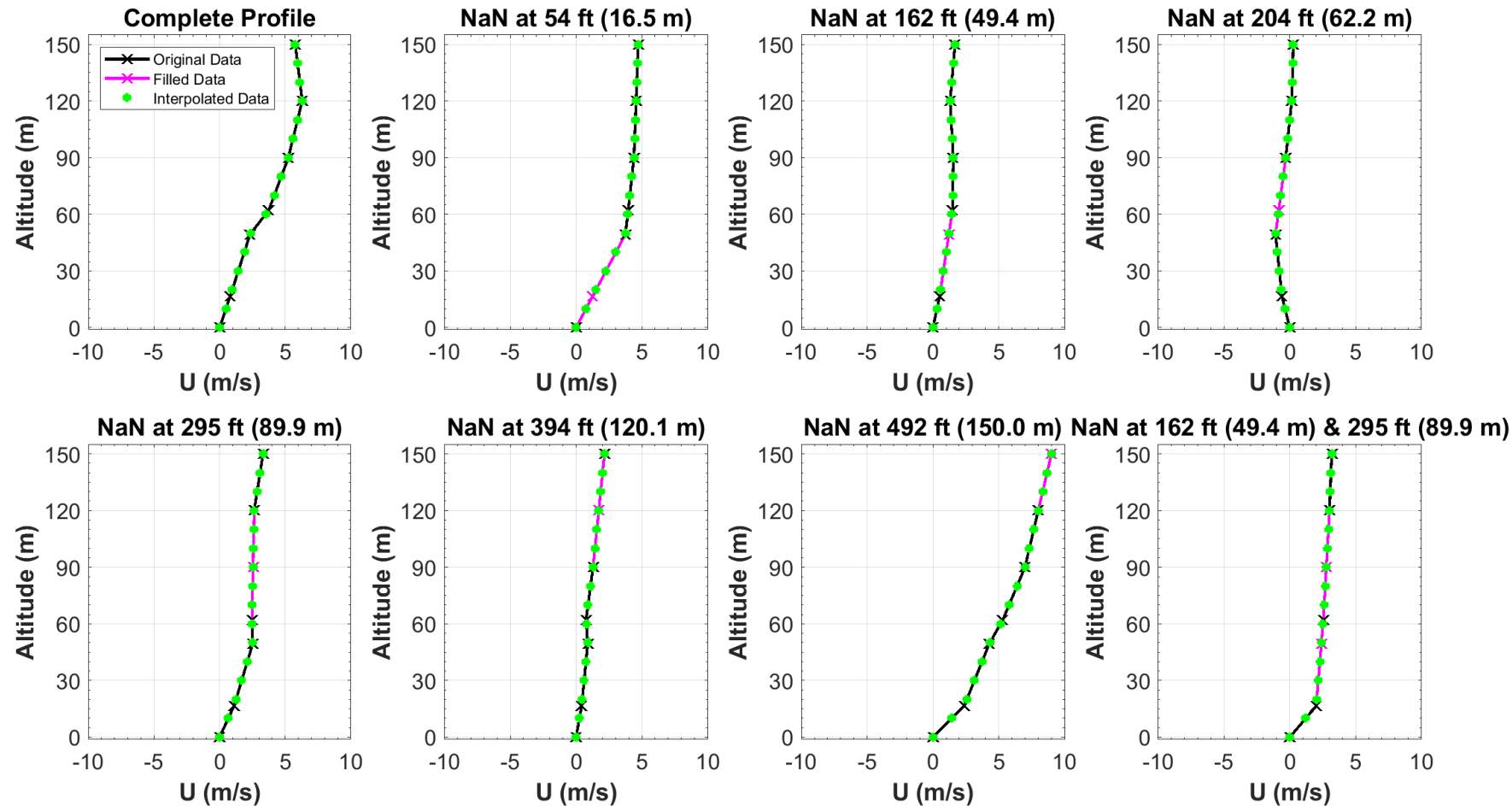
## Vertically-Complete Duodecaplets

- 10-m altitude increments below 200 m.
- Thermodynamic data interpolated
  - Temperature: linear
  - Pressure and density: log
- Ground winds added below 250 m.
  - No change to the L-6 hour profile.
- For all subsequent profiles:
  - Tower-measured wind components from 0-150 m, when available.
  - Wind component at 200 m is the mean of the report at 150 m and 250 m.

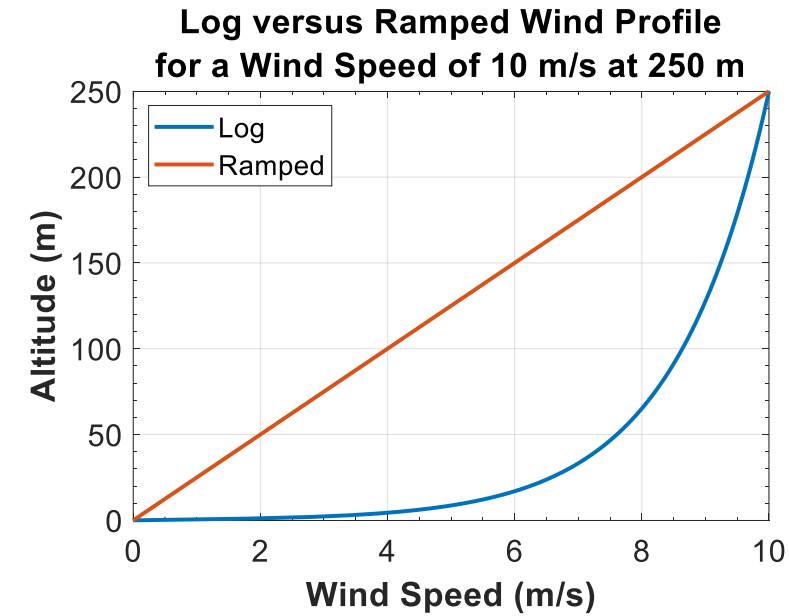
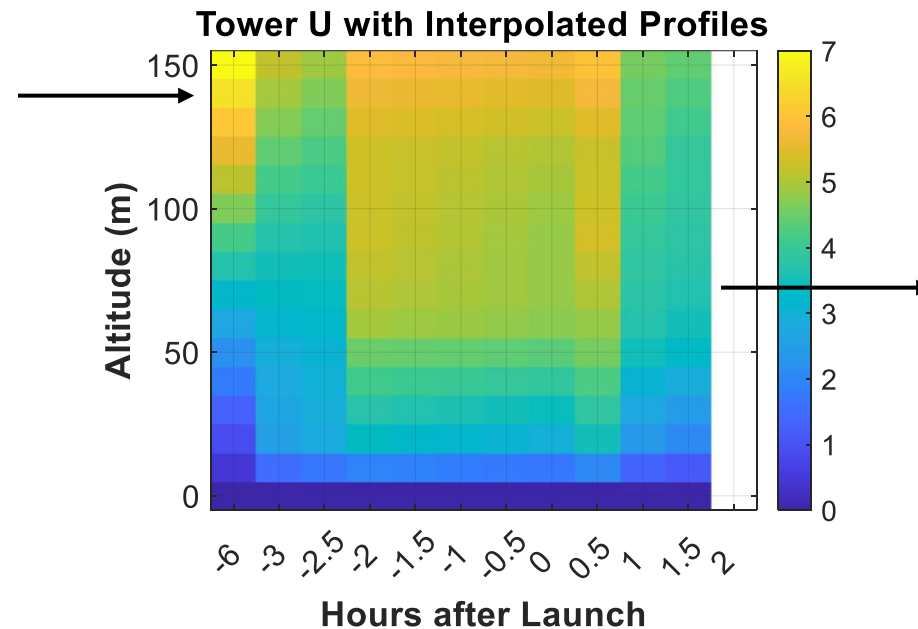
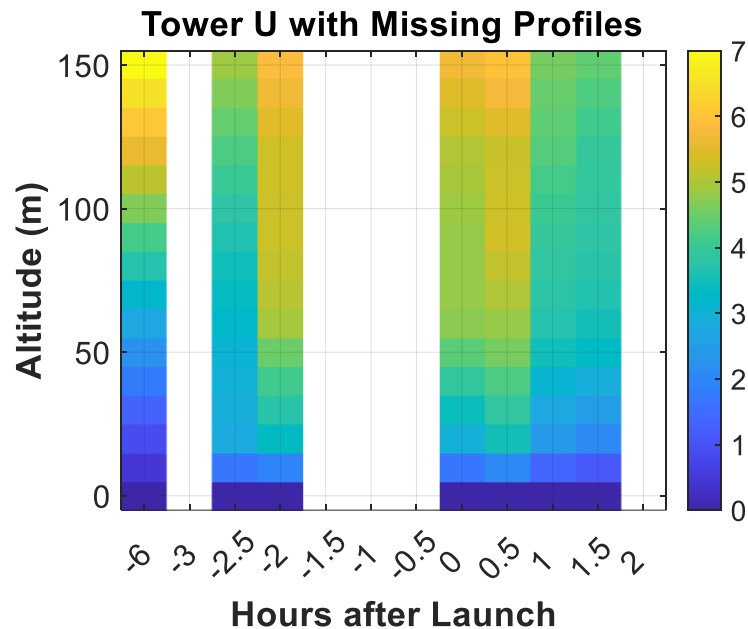


# Tower wind components were preprocessed to match the output temporal and vertical intervals.

- 1) Quality controlled 5-min mean winds from 2000-2009.
- 2) Computed 10-min mean wind components.
- 3) Used profile if no consecutive gaps from 17-150 m. A total of 88% of the 1,385,076 profiles passed check.
- 4) Forced 0 m/s wind at 0 m.
- 5) Interpolated wind components to 10-m intervals from 0-150 m.
- 6) Used the closest tower profile to a given DRWP profile if separated by no more than 15 minutes.



Output below 250 m was generated through interpolation of tower data versus time or using the log wind profile model if tower data were not available.



- Tower data at L-6 hours are used for interpolation versus time, even though no tower data at L-6 hours are added to the duodecaplets.
- No extrapolation versus time is performed.

$$u(z_2) = u(z_1) \frac{\ln((z_2 - d)/z_0)}{\ln((z_1 - d)/z_0)}$$

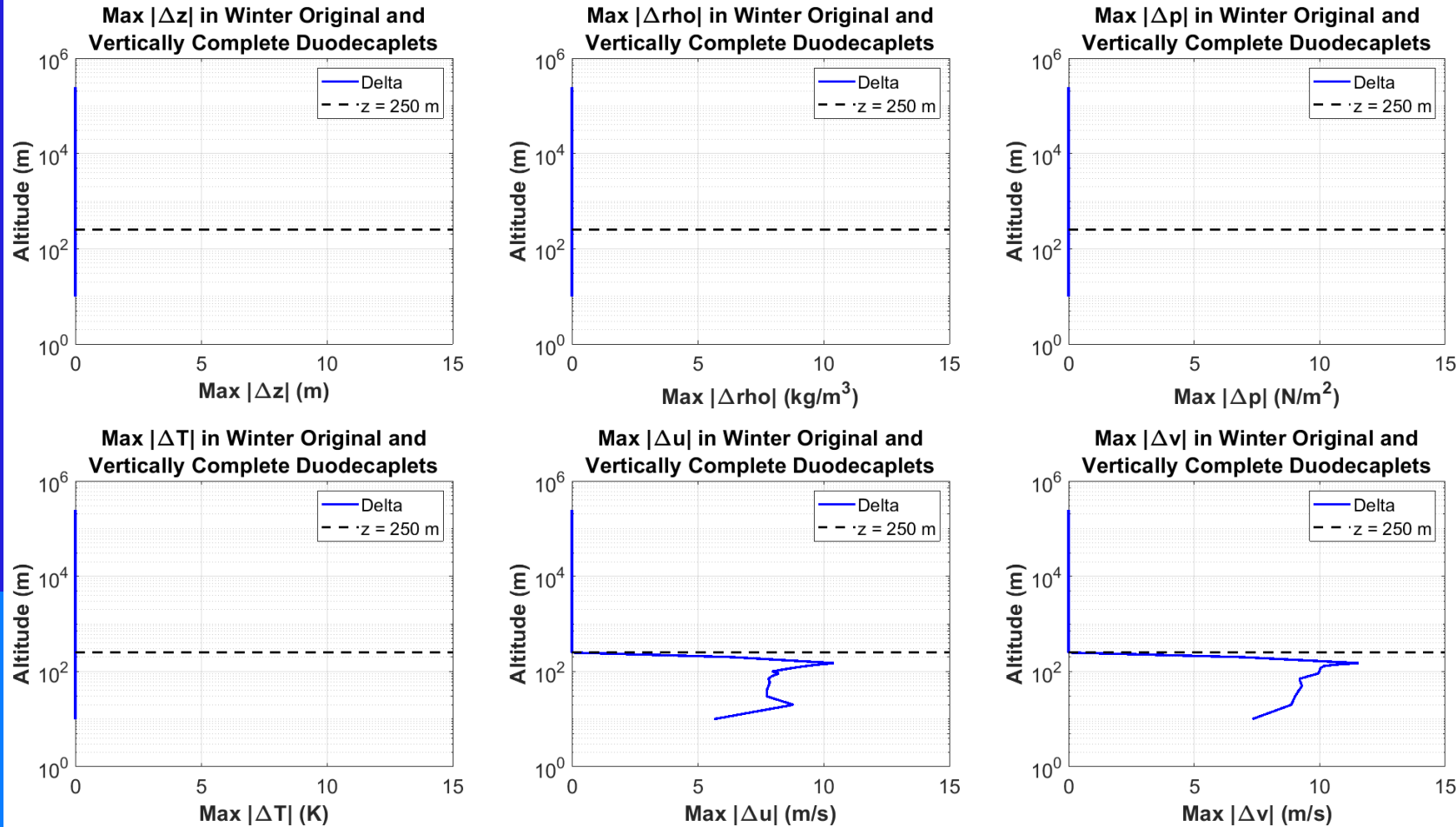
- $z_1$  set to 250 m,  $d$  set to 0 m.
- Roughness length  $z_0$  set to 0.3 m.
- Wind direction held constant.

# Source of ground wind profiles

| Percent of Profiles (L-3 hours to L+2 hours) from Each Source |        |                          |                        |
|---|--------|--------------------------|------------------------|
| Season  | Tower  | Interpolated versus time | Log wind profile model |
| Summer (N=61,050)   | 98.82% | 0.59%                    | 0.58%                  |
| Transition (N=41,789)   | 97.35% | 1.06%                    | 1.59%                  |
| Winter (N=40,865)   | 95.46% | 0.81%                    | 3.73%                  |

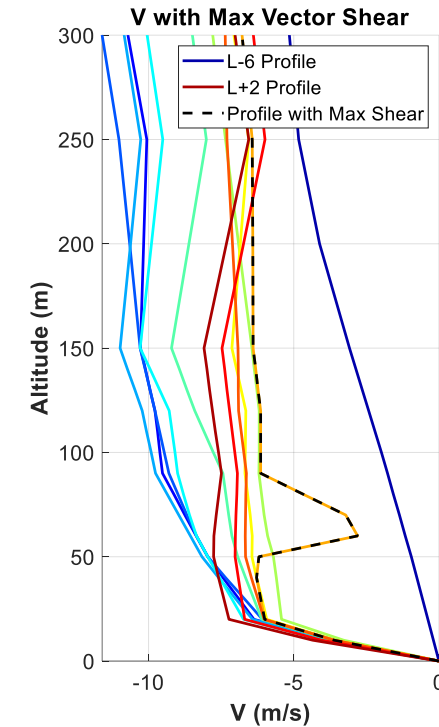
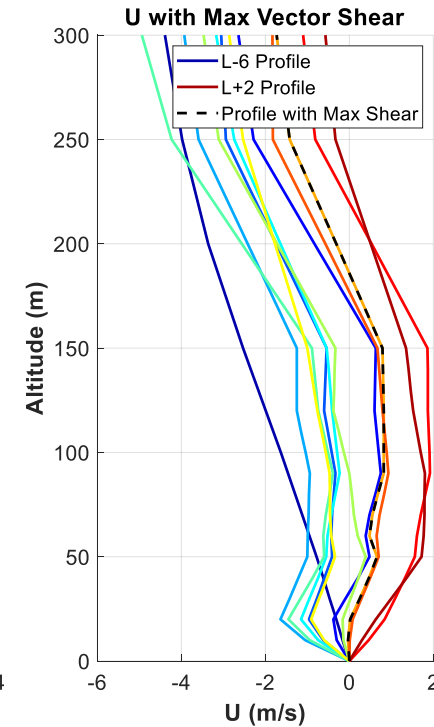
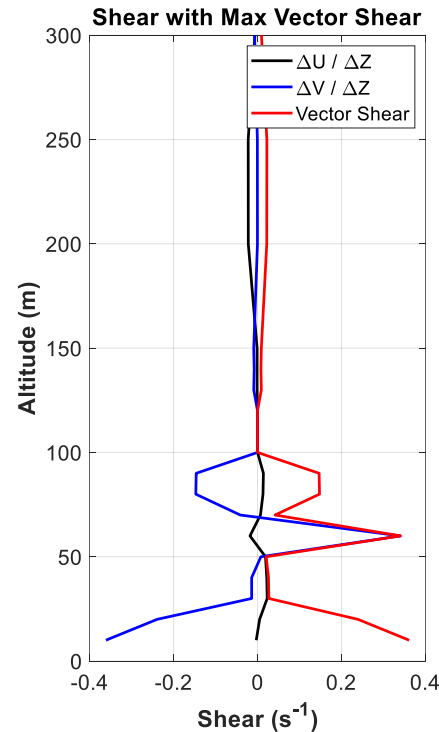
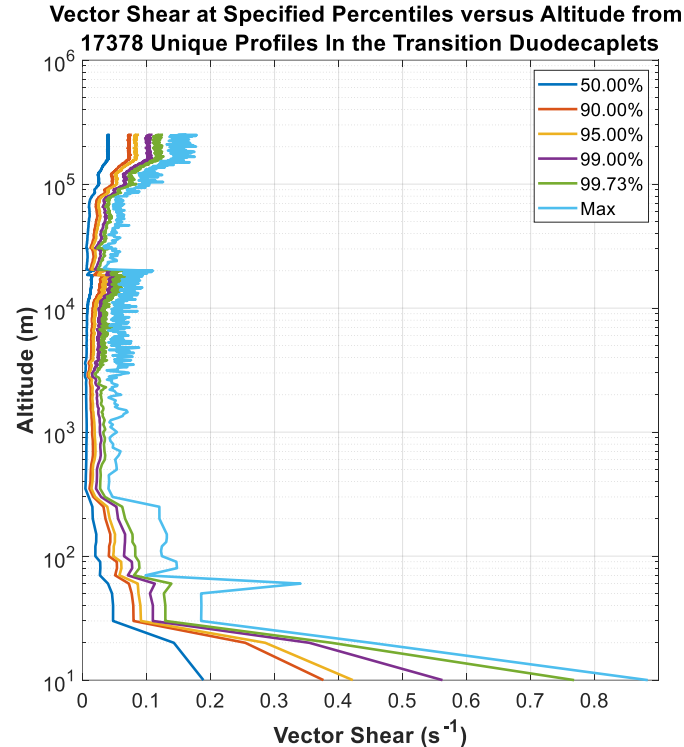
- Did not examine the L-6 hour profile as it did not have any tower data.
- Over 95% of all vertically-complete duodecaplet profiles contain tower data.
- Approximately 0.6-1.1% of the profiles contain interpolated tower measurements.
- Roughly 0.6-3.7% of the profiles contain profiles from the log wind profile model.

# Verified that the only changes to the previous duodecaplets occurred at altitudes below 250 m.



- Plots show the maximum difference magnitude between the previous and vertically-complete duodecaplets.
- Interpolated previous duodecaplets to the altitudes of the vertically-complete database.
- Pressure and density are equivalent to five decimal places, which matches the precision in the output files.
- Analogous results exist for all seasons.

# Computed shear versus altitude to verify the application of tower measurements.



- Tower data screened for excessive shears as part of data QC.
- No evidence that splicing produced any artificial shears.
- Examined tower data in the duodecaplet with the highest shear.
- Example of a duodecaplet with suspect shear. Also found some cases influenced by tropical systems.

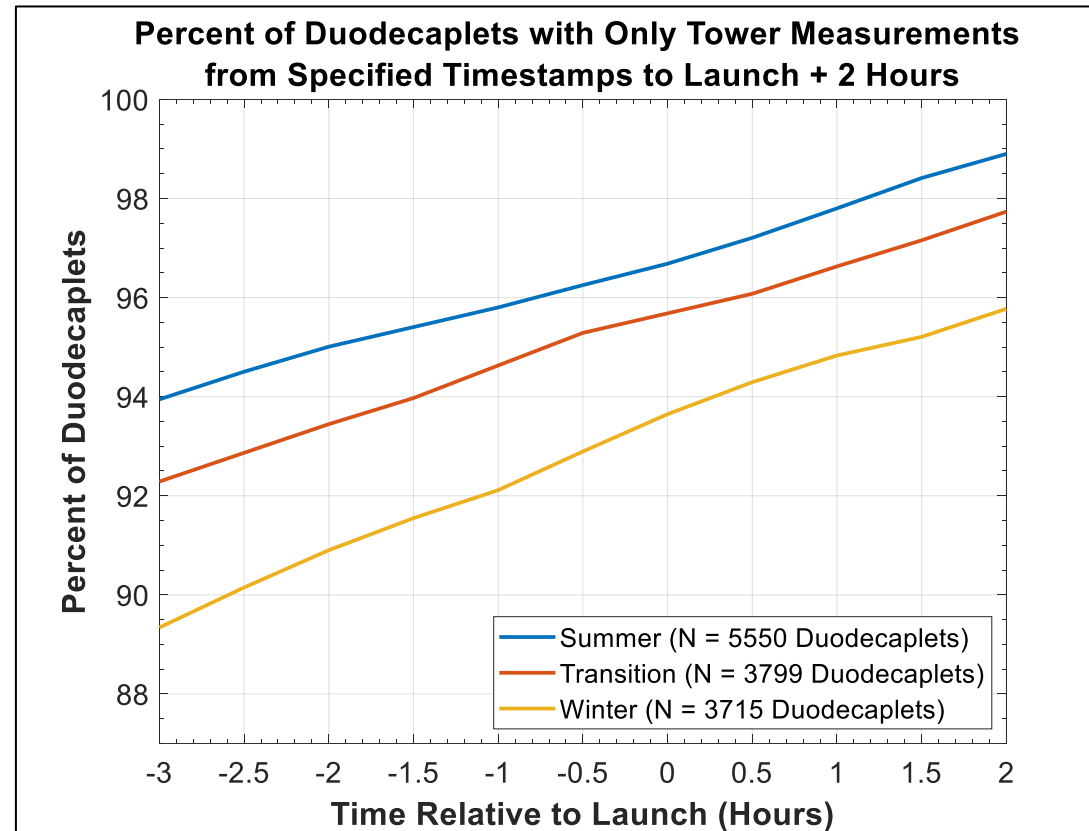
# The vertically complete duodecaplets have been reviewed within MSFC Natural Environments and presented to various technical forums.

- Verified that no wind component differences existed from the original duodecaplets above 200 m altitude, and no differences existed in thermodynamic data at any altitude.
- Quantified the instances of ground wind profile sources.
  - At least 95% of the profiles in each season have tower profiles.
  - At least 89% of the duodecaplets in each season have tower data representing ground winds for all profiles.
- Future work needed to examine suspect shears in the database, and eliminate profiles affected by tropical systems. Orion has also requested MSFC NE to add vertical wind components to database.
- The database was approved to temporarily use as-is for Artemis II Mission Analysis Cycle pad abort assessments and address above issues with a future update. The plan is to then use the updated database for all future assessments.

**Backup**

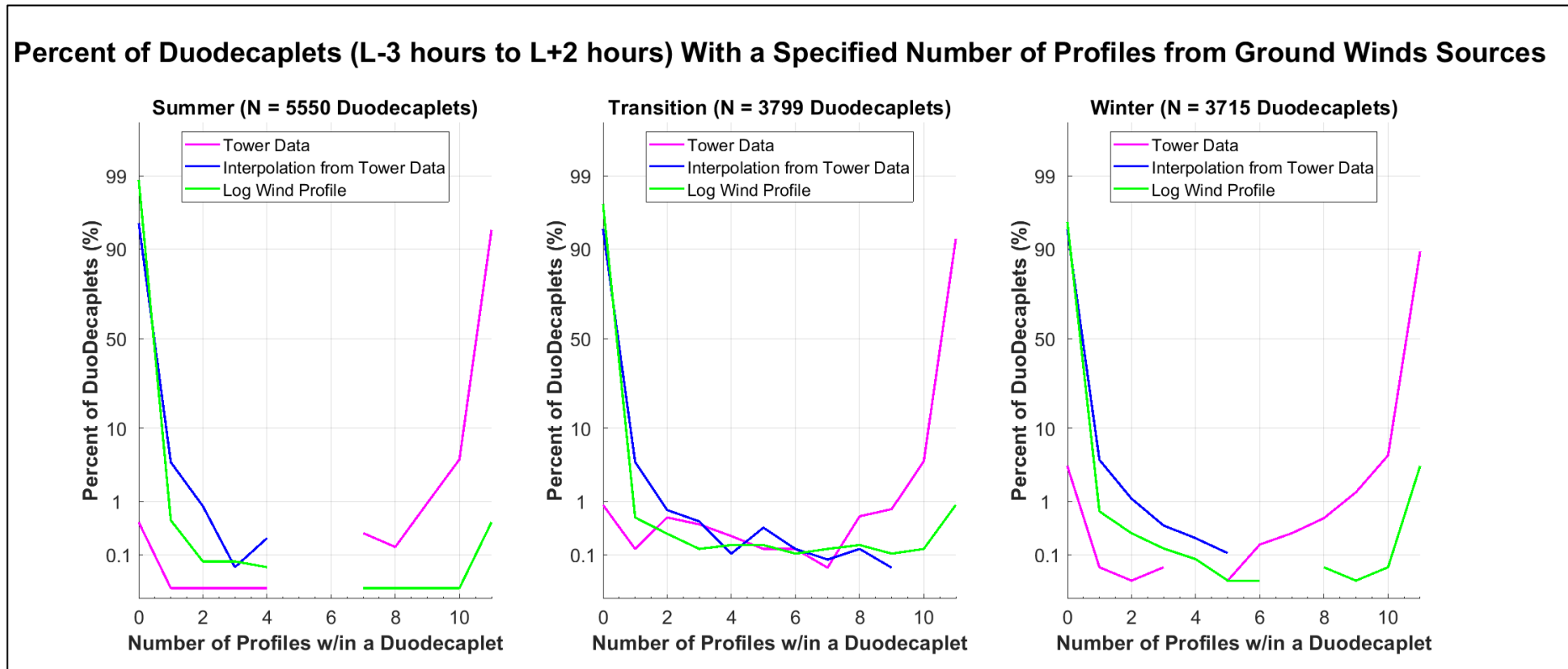


# Quantified the instances of using each ground winds source.



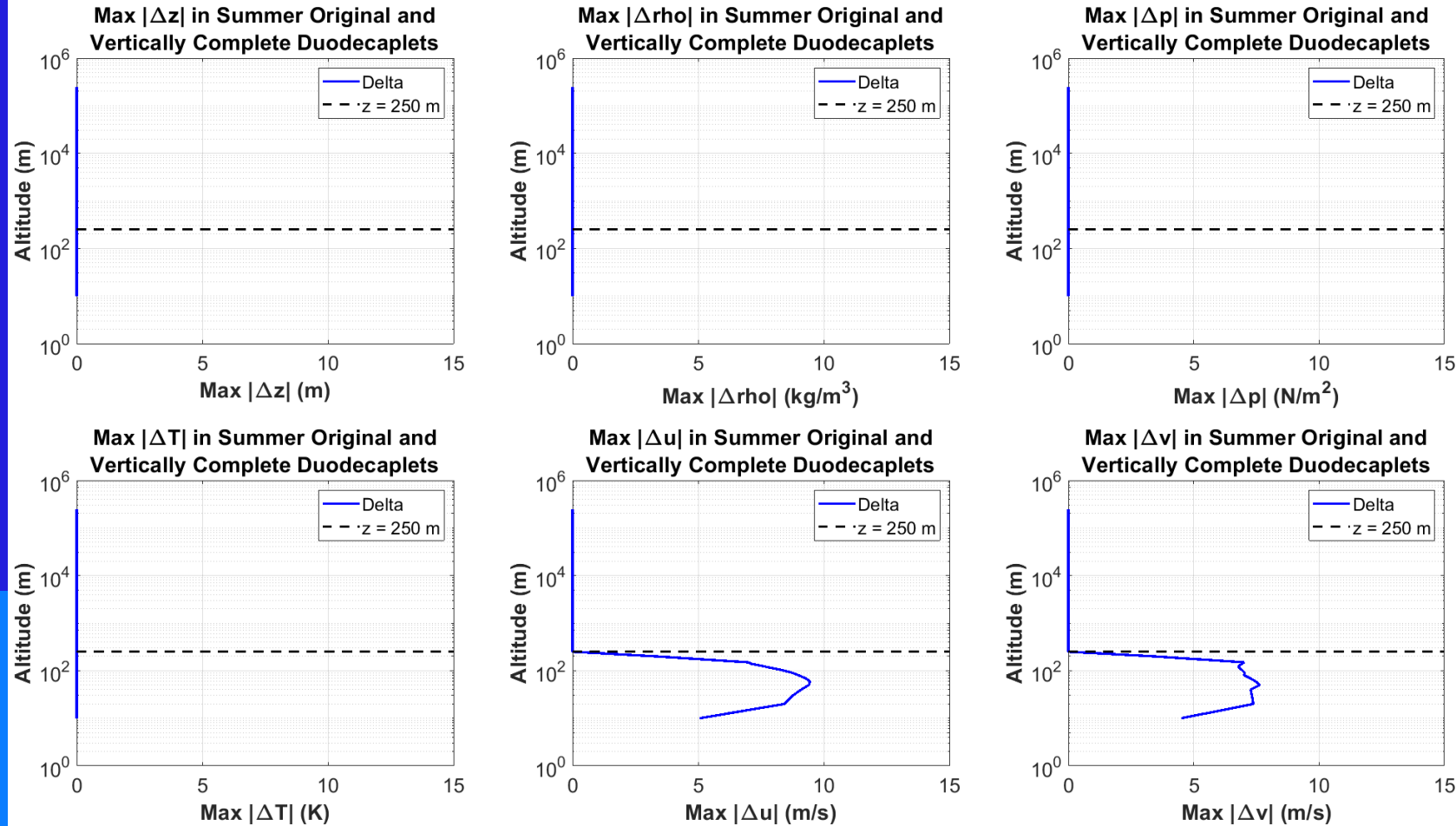
- At least 89% of all duodecaplets have tower data from L-3 to L+2 hours for a season.
- Roughly 95%, 93%, and 91% of the duodecaplets have tower data at all profiles from L-2 to L+2 hours for Summer, Winter, and Transition, respectively.

# Quantified the instances of using each ground winds source.



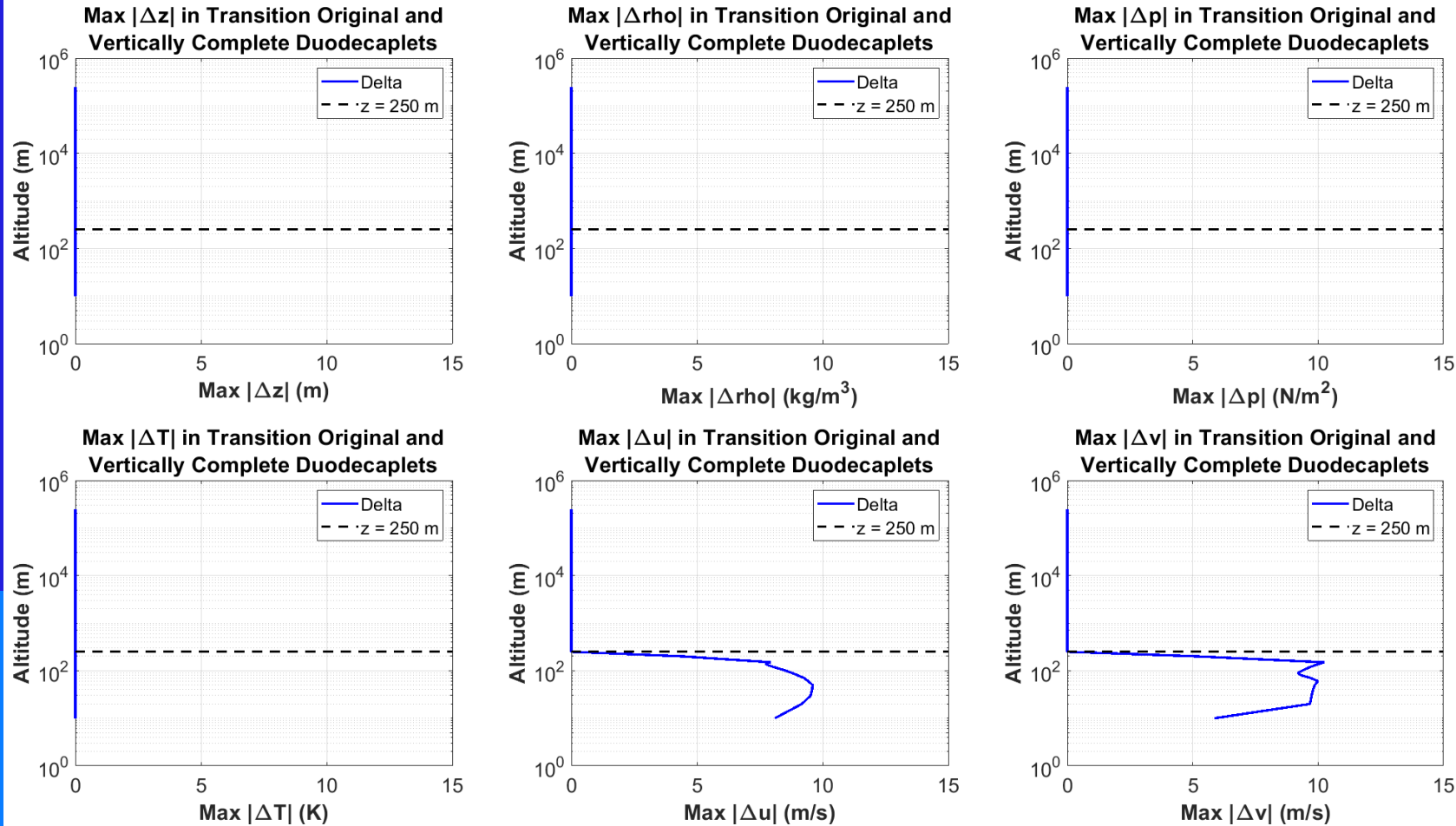
- Less than 1% of all Summer and Transition duodecaplets do not have any tower data.
- Graphs show sensitivity to the number of tower profiles in the duodecaplets. For example, roughly 0.1-0.3% of the duodecaplets have four profiles from interpolated tower measurements.

# Verified that the only changes to the previous duos occurred at altitudes below 250 m.



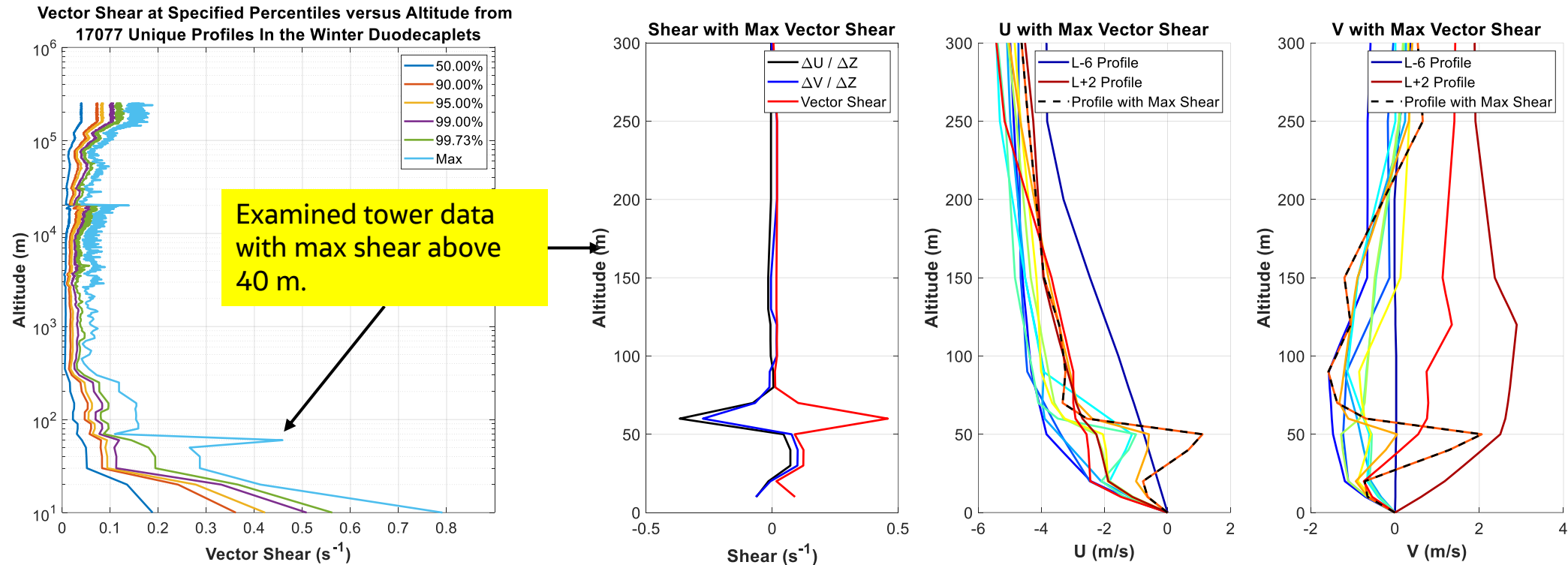
- Plots show the maximum difference magnitude between the previous and vertically-complete duodecaplets.
- Interpolated previous duodecaplets to the altitudes of the vertically-complete database.
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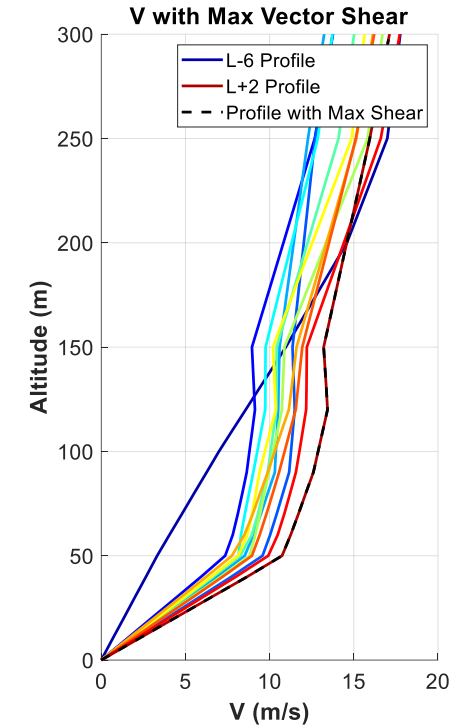
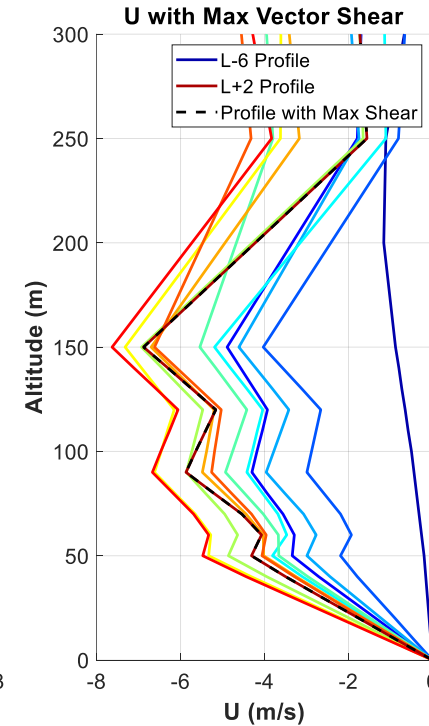
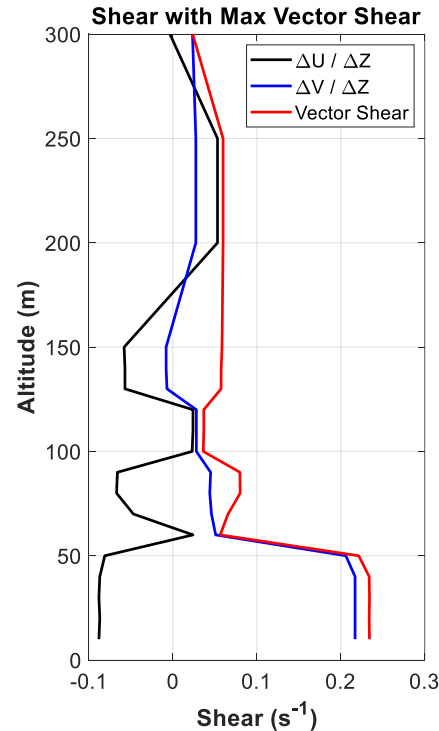
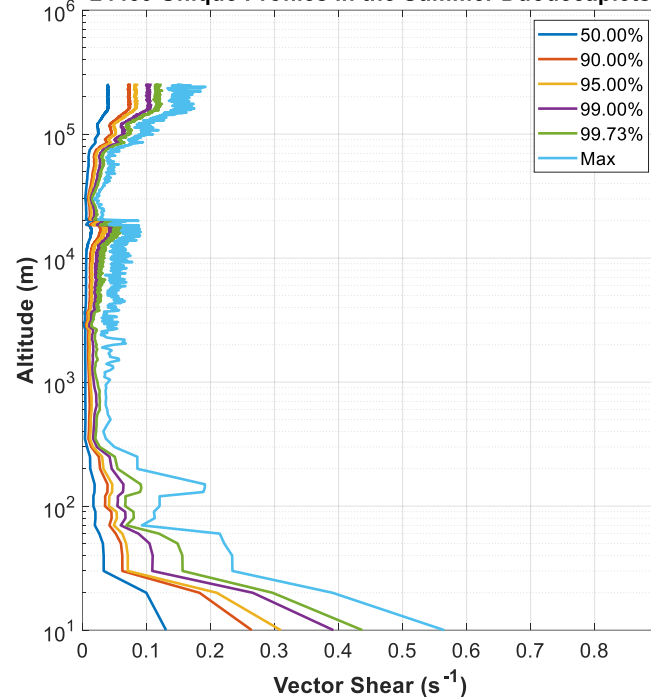
# Computed shear versus altitude to verify the application of tower measurements.



- Tower data screened for excessive shears as part of data QC.
- No evidence that splicing produced any artificial shears.
- Examined tower data in the duodecaplet with the highest shear.
- Max shear in Winter was found at 60 m following a trend with other profiles in the duodecaplet of interest.

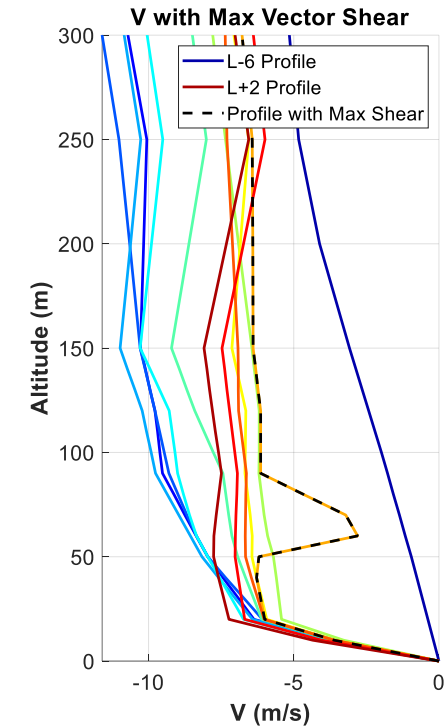
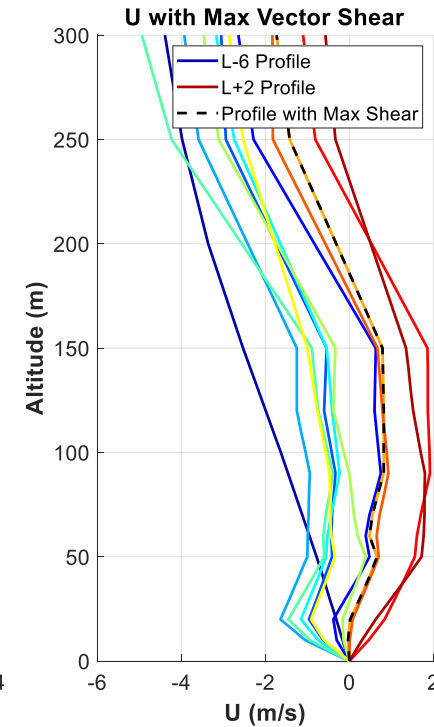
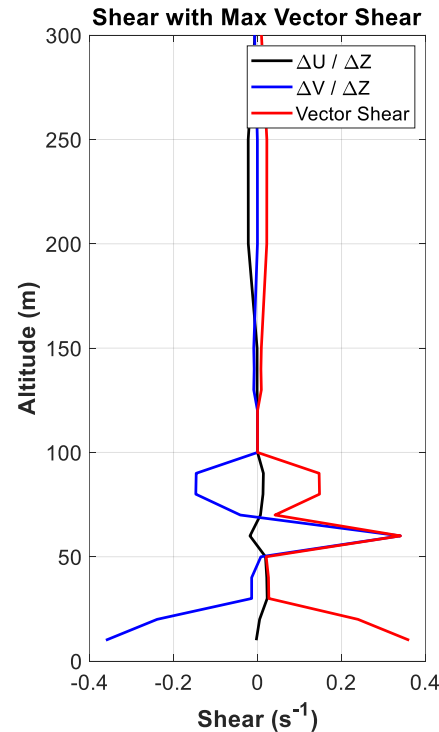
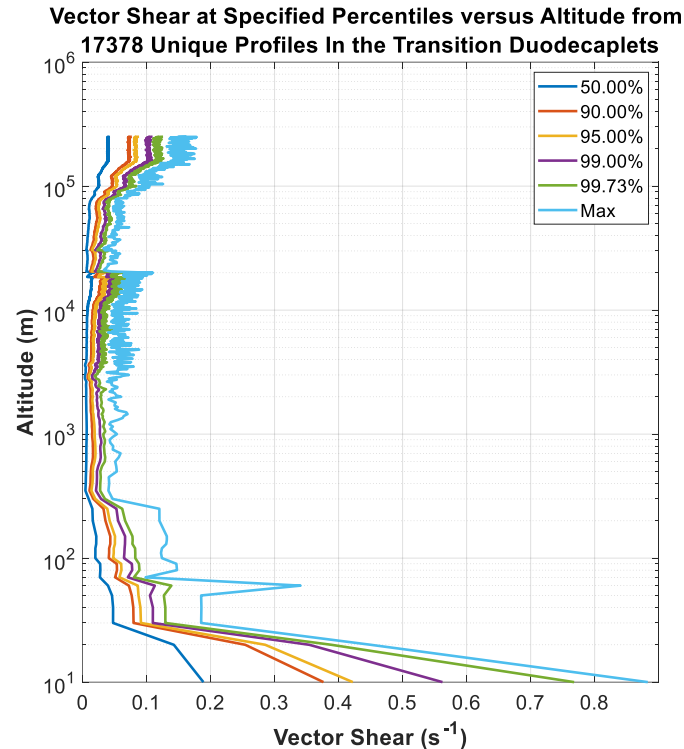
Max summer shear was found at 50 m following a trend with other profiles in the duodecaplet of interest and suggesting ramped winds below 50 m.

Vector Shear at Specified Percentiles versus Altitude from 24439 Unique Profiles in the Summer Duodecaplets



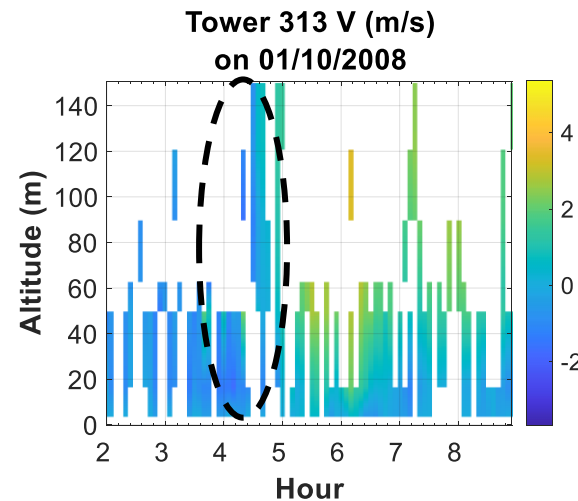
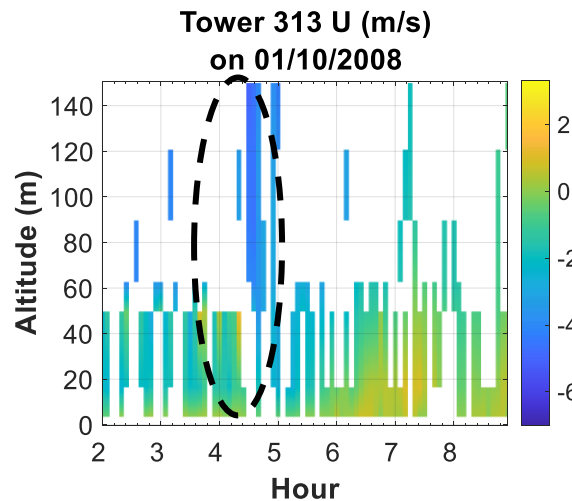
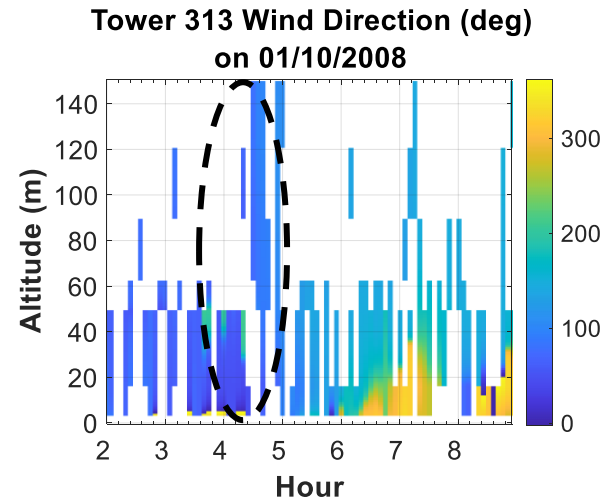
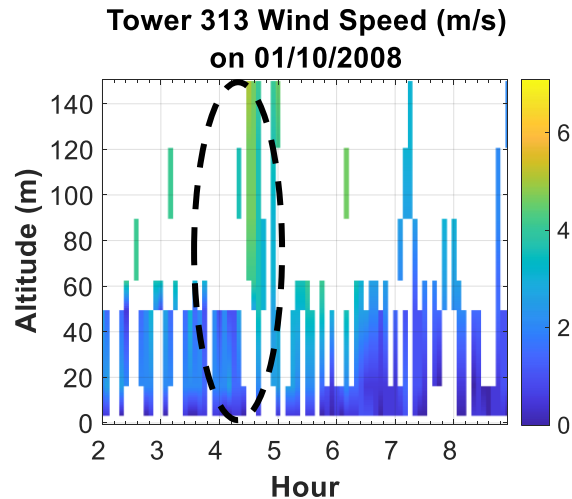
- Max shear found on 8/22/2008 at 2321 UTC.
- Lowest data record existed at 49 m (162 ft).
- Persistent wind speeds of  $\sim 10$ -15 m/s warranted further investigating, which found this event to be associated with Tropical Storm Fay.
- Duodecaplets were not screened for tropical systems.

Max shear in Transition was found at 60 m with an apparent outlier in V as compared with other profiles in the duodecaplet of interest.



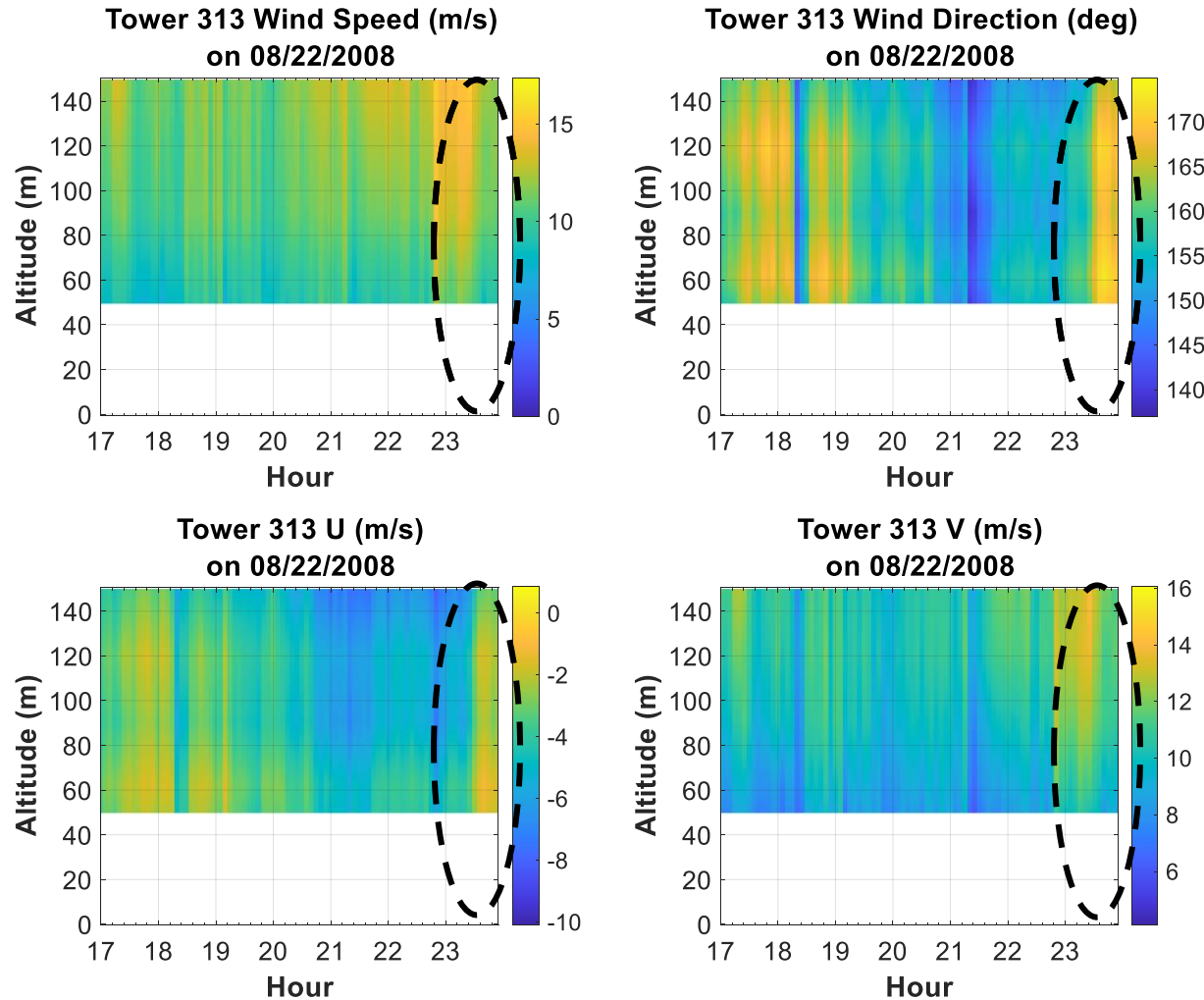
- Max shear found on 4/8/2008 at 1422 UTC.
- Shear stems from an outlying decrease in wind speed that passed the tower data consistency checks.
- Winds were from the north, so the change is apparent in V with  $U \sim 0$  m/s.
- Example of a duodecaplet with suspect shear.

# Tower data with max winter shear show increasing wind speed with altitude.



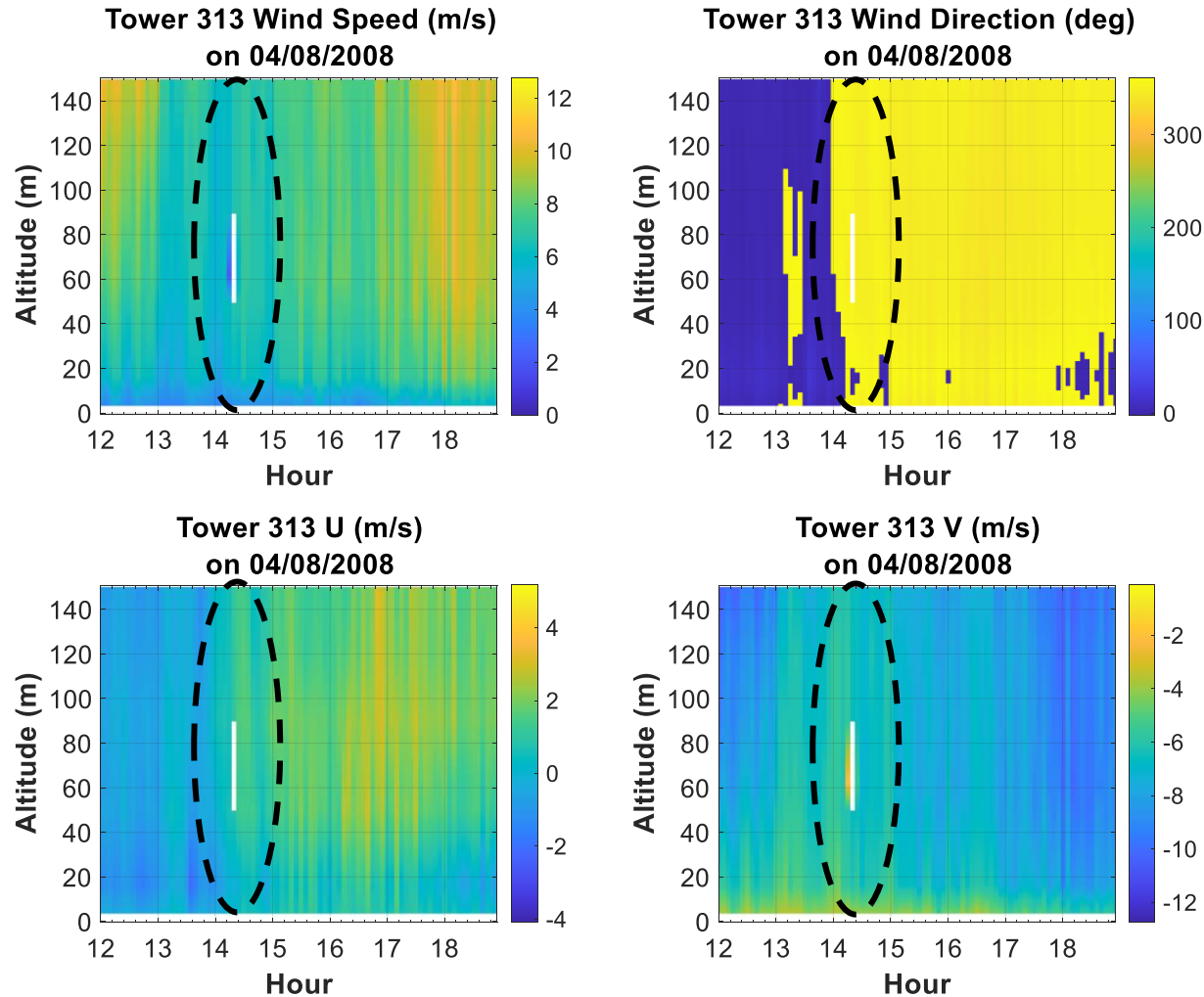
- Max shear found on 1/10/2008 at 0425 UTC.
- Increasing wind speed with height noted from ~0400-0500 UTC.
- Tower data are in duodecaplets because of the consecutive gap tolerance.

# Tower data with max summer shear show valid winds in a tropical system.



- Max shear found on 8/22/2008 at 2321 UTC.
- Lowest data record existed at 49 m (162 ft).
- Persistent wind speeds of ~10-15 m/s warranted further investigating, which found this event to be associated with Tropical Storm Fay.
- Duodecaplets were not screened for tropical systems.

# Tower data with max transition shear show an outlying decrease in wind speed.



- Max shear found on 4/8/2008 at 1422 UTC.
- Shear stems from an outlying decrease in wind speed that passed the tower data consistency checks.
- Winds were from the north, so the change is apparent in V with  $U \sim 0$  m/s.
- Example duodecaplet with suspect shear.